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CONWIP AND ITS IMPLEMENTATION

Assignment 3 of

Production Management course

VAASA 2014

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1. INTRODUCTION

High competition in the markets forces the companies to operate more efficiently. In this course, the main emphasis is on variability in production systems and how to overcome the problems related to it. So, in this report we will mainly focus on this issue. Throughout the history, many different approaches have been developed which started with mass production. Push systems, pull systems and hybrid push-pull systems have been used in different forms. After successful implementation of kanban system in Toyota factories, it spread to the other parts of the world also. But nowadays, some drawbacks related to kanban system have aroused. It is difficult to apply it in many cases; it needs trainings and much time to fully adopt it to a company. The workers' resistance to change is also another major problem. In this paper, different approaches will be discussed along with their advantages and disadvantages. Then, CONWIP system will be explained as a pull-based alternative to kanban system. Then, different scenarios will be described on which CONWIP system would have the most and least impact.

The next section explains how CONWIP system can be integrated production planning and control based ERP systems. Then, implementation of CONWIP to push, pull and jobshop facilities will be described. The report ends with summary and conclusions.

2. DISCUSSION OF DIFFERENT PRODUCTION SYSTEMS

The ideas discussed in this part are taken from the article "CONWIP: a pull alternative to kanban" by Spearman et al (1990). The main questions for the production firms are producing the right parts at right time at a reasonable cost. There are two types of production systems used worldwide: pull and push systems. Companies using push systems employ Material Resource Planning (MRP) and its modern version MRP II. Most of the time, push systems result in less effective utilization of resources. An alternative for push system is pull system. In general, Just-In-Time (JIT) philosophy was first employed by Japanese, in Toyota Production Plants. A special method of JIT philosophy – kanban has been applied in many cases yielding more efficient results.

Now, we will discuss the main problems related to push and pull systems. Push systems are used in forms of MRP and MRP II in practice. Push systems do not always generate feasible productions and it most of the time it is not possible to reveal it until the last moment. This happens because capacity of a production line is not deterministic and determining it is challenging. Capacity depends on many factors which cannot be controlled. The second drawback related to push systems is that MRP uses fixed lead times. In fact lead times are random, and to decrease the risk of shortage, the companies produce more than needed. This increases the variability in the system, resulting in higher WIP levels.

Pull systems do not schedule the production level, but use in the downstream operations authorizes the start of the production at the upstream station. Mostly, pull system is used in form of kanban. The word “kanban” means “card” in Japanese language. Each card represents a part (or a batch of parts) to be produced, thus the number of the cards determine the WIP level in the system. The main advantages of such systems are shorter flow times due to decrease in the WIP level in the production system. But kanban system requires that the system runs smoothly, the scrap losses, significant setups and accelerated productions hits the system badly.

There have been several attempts to use a mixed model of push and pull systems in the past. Synchro-MRP system that was proposed by Hall (1981) has been one of the first of such attempts. The scheduling is done according to MRP, but authorization was done according to the kanban cards. This method had many similarities with the CONWIP system that will be discussed in this paper.

Next, the authors discuss the advantages of pull systems over push systems. The reasons of superiority are divided into three categories:

1. Environmental effects,
2. Queuing effects,
3. Control effects.

We start by discussing the environmental effects. Pull systems, especially kanban cannot be applied to every production company. There are several factors that may make it meaningless to apply kanban. They are listed as follows:

a. Orders of variety of products each with short production run
b. High set-up times
c. Scrap losses
d. High variation in demand

On the other hand, MRP can be applied in almost any production firm.

Main advantage of the kanban system is that WIP inventory is kept under control. As the system kanban system works, the number of kanban cards can be further reduced. The reduction in inventory reveals the problems of the production facility. Actually this helps ambitious companies that aim to uncover the problems and repair them. Most of the time the problems cannot be directly observed in a production facility i.e., the determination of problems is itself a challenging question due to complexity and mutual interactions. The reduction of inventory that kanban results in, reveals the problems such as machine inefficiencies, break-downs, scrap levels, etc.

The main superiority of the kanban system over push systems is that it requires environmental improvements to be applied.

Next, the queuing effects are discussed. The difference between pull and push systems can also be interpreted as follows. Push systems plan the throughput and measure the WIP, but pull systems schedule the WIP and observe the throughput. In this sense, push systems can be described as open queuing networks and pull systems as closed queuing networks. CONWIP also resembles the pull systems, because it is also closed queuing network, which will be discussed later. Spearman et al. discuss a simulation study that it has been shown that closed systems result in lower WIP that open systems under the same conditions. This implies that flow time will be lower for a closed system and also the variance of the flow times is proven to be lower for pull systems. Reduced mean and variance have mutual benefits, they both imply reduced WIP and Finished Goods Inventory (FGI).

Lastly, control effects of push and pull systems will be discussed. In push systems, the fluctuations in WIP and TH rate imply that actually flow times are random variables, which is assumed to be constant in push systems. This can be easily derived from the Little`s Law:

Flow Time = WIP/TH

Actually, cycle time is a function of WIP and TH, not constant.

The fact that optimizing WIP inventory level is far easier than throughput is another advantage of the pull systems.

If a company operates near the full utilization rate, the throughput stays constant most of the time. But if WIP is not kept under control, flow times will increase significantly which is not a desirable case. This case is depicted at the following graph:

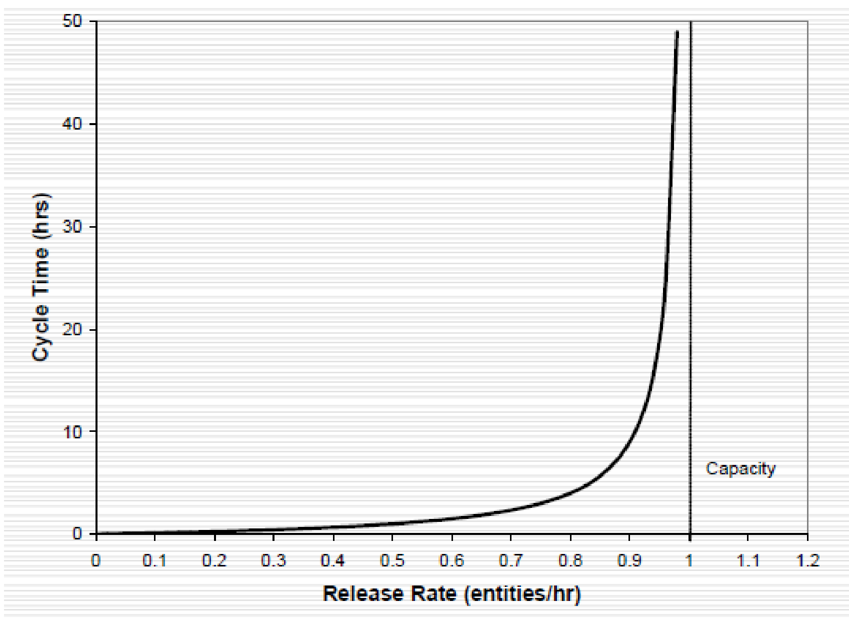

Fig.1 Cycle Time vs Utilization Level

As the release rate approaches the capacity, cycle time (also flow time) grows seriously. Since WIP inventory is always under control in pull systems, the abovementioned problem is never encountered.

Spearman et al. (1990) argue that pull systems can be controlled easier than push systems. First of all, WIP levels are easier to observe while capacity is not. In fact, capacity calculation is not easy because of the reasons discussed in the previous parts of the paper. The authors also note that errors in the capacity calculation hits the system much more that errors in WIP calculations.

3. INTRODUCING CONWIP

CONWIP (CONstant Work In Process) is a pull-based alternative for kanban. It shares the advantages of the pull production systems and can be used in more manufacturing environments than kanban. CONWIP is also operated using signals like kanban. The card (it can also be electronic) is attached to the container at the beginning of the production process and returned back to the beginning when the container is processed. The main difference of CONWIP from kanban system is that in CONWIP, each card does not represent a specific part. The part numbers are assigned according to the *backlog* list. This process is visualized as follows:

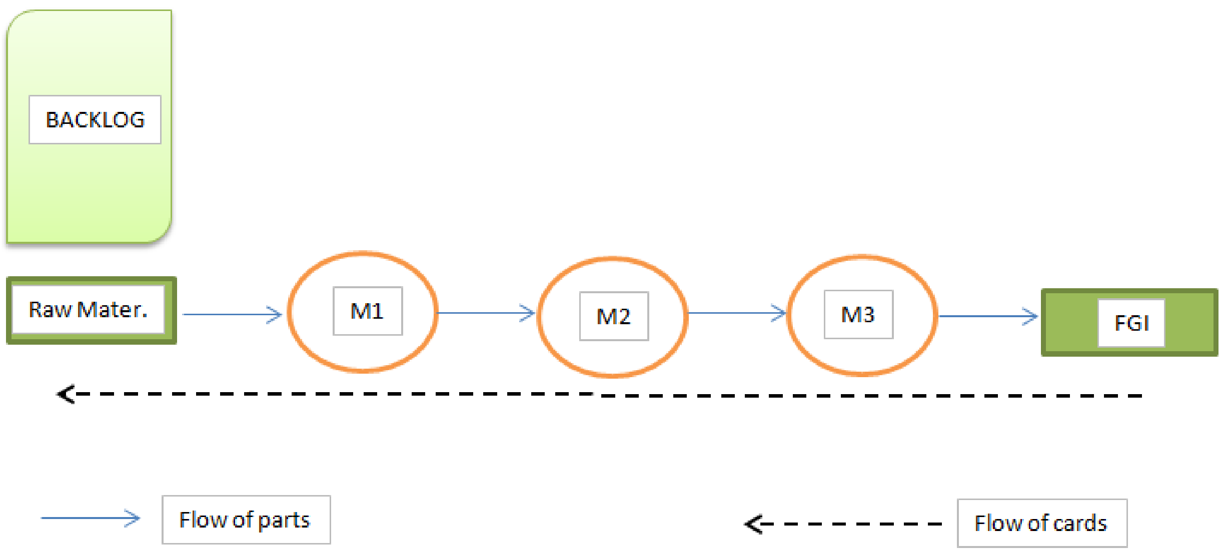

Fig. 2 Visual presentation of the CONWIP model

Here, the backlog is generated and administered by the production department most of the time using master production schedule. But the production cannot be started without a card present at the beginning of the production process. The queue discipline is First in System First Served (FSFS), except for the reworks. Reworks have higher priority than the others.

There are four parameters for the CONWIP system:

- m – number of cards

- q – target production quantity (for a given period)
- n – maximum work head amount
- r – capacity shortage trigger.

The optimization of these parameters is a challenging issue, but the companies can improve them after some time according the performance of the system.

CONWIP is a good system for input/output control at the production floor level. It is regulated by the bottleneck resource. Actually, the performance of the CONWIP system depends on the bottleneck. If bottleneck processes the parts quickly, the cards will be recycled quickly and vice versa. CONWIP makes bottleneck busy most of the time but not allowing the parts to pile up behind the bottleneck. This helps to prevent the flow times from growing dangerously.

Based on the information provided above, we can discuss the scenarios that applying CONWIP will have the most and least impact on the current production system. Choosing the appropriate production system for a firm should be decided considering several factors.

Product mix: can changing or constant.

Setup times: can be high or low.

Order arrivals: can have high or low variance.

At the beginning of the paper, it was discussed that pull systems are more efficient than push systems and CONWIP is a pull based system.

If the company is doing mass production with long runs, probably CONWIP will have the least impact, because kanban is more useful in this case. But if the company is has changing product mix, high setup times and/or has short runs of small setups; CONWIP would have more impact on the production system.

4. IMPLEMENTATION OF CONWIP

Before going into detail about the topic, it is worth mentioning that CONWIP systems need continuous monitoring of the production performance. Since the main focus of all pull systems is to decrease the inventory in the system, a sudden change in customer order may cause problems. As discussed at the previous sections, the setup levels should also be kept under control. The production department should monitor the number of parts in the system, the processing times of machines, etc.

Luftensteiner et al. (2011) discuss how to apply CONWIP in manufacturing environment that customer orders are highly varying. They propose that in this case, “maximum WIP level” parameter should not be used. There are two alternatives:

1. Limiting the order quantities if possible.
2. There will be no max WIP level. The rule to limit the jobs in the system is releasing as many jobs as bottleneck will be always busy.

4.1 Implementation in Jobshop Facility

Jing-Wen Li (2010) discusses how CONWIP can be implemented in a jobshop manufacturing environment. He notes that the current competitive market forces the companies to maintain continuous improvement. Production control functions like ERP play an important role in continuous improvement. But as discussed before, assuming fixed lead times creates several problems, increases variability which results in increased flow times. It has been proven that CONWIP always performs better than push. Other pull systems like kanban also perform worse in jobshops where there is high product variety. The author gives four key conditions to implement CONWIP system effectively:

1. Production control approaches – Company that wants to employ CONWIP should change its approach to production control. The principles of pull system should be fully understood by the management.
2. Shop layout – Assigning the machines with similar functions into one department is called functional layout. The traditional functional layout is not effective for CONWIP system. Since the CONWIP system controls the number of products in the system,

cellular layout is more effective. Cellular layout combines machines needed to produce a specific product or families of product. In CONWIP system, the cards are assigned to individual cells.

3. Setup time reduction – In order to implement CONWIP system, setup time reduction is of paramount importance. All pull systems are very sensitive to high setup times, they deteriorate the overall performance and at some point, even push system becomes more useful. Applying cellular layout already reduces the setup times (due to low volume-high variety). Thus, lead time decreases, which is one of the main aims of the CONWIP system and is also important factor to apply it. CONWIP offers more flexibility in sequencing the jobs, because as opposed to kanban, the parts can move more freely within the system. This results in setup reduction already.
4. Quality performance – The last condition for applying CONWIP is that the company should achieve low scrap and rework levels. If the scrap/rework level is high, the variability in the system increases, which results in high WIP levels which is undesirable.

The author explains his simulation model and sets numerical levels using sensitivity analysis. He has four major performance measures related to the four key conditions mentioned above:

a. Setup time reduction (STR) – it measures the level of setup time reduction which is a key condition for implementing CONWIP.
b. Layout and Production Control (LPC) - this measure is related to production control and layout.
c. Mean magnitude of step shifts (MMSS) – related to quality.
d. Probability of occurrence of step shifts (POSS) – also related to quality.

According to the results of the simulation, Li defines the minimum levels for these performance measures that make it useful to apply CONWIP system for a jobshop facility. He points out that, setup reductions must be at least 70 % in order to be able to implement CONWIP system effectively.

4.2 Implementation in Push System

If the current production environment is push system, there is more room for improvement using CONWIP system.

In push system, the planning is done using Manufacturing Resource Planning (MRP II) and implemented accordingly. In this case, the company can use the data from ERP to calculate the maximum WIP level for the production system. Then, the company continues using ERP for planning, but implementation phase is changed. The planned items are not released to production until the place is freed for it in the system.

Gastermann et al. (2012) discuss how to implement CONWIP in firms with existing conventional production planning methods. They start by discussing different approaches to production planning and control and highlight the advantages of CONWIP. One of the main advantages is that it can be easily implemented with unskilled staff. For example, kanban needs much effort, training and skilled workers to make it run properly. Production order list is prepared to plan and trigger the release of orders. The list is filled with work orders from MPS that is independent of production control system. Work-ahead-Window (WAW) is a time frame to regulate the production level. That is, in low selling periods, the production level is decreased instead of keeping it constant.

The authors also describe an application of these ideas in a firm operating in the plastics industry. They divide the whole production process into two phases. In the first phase, the raw materials are processed according to Make-to-Stock (MTS) system. In the middle of the production process, there is buffer of semi-finished goods. From that point to the end of the production process, CONWIP is employed. This point of transition from MTS to MTO is called the “Order Penetration Point” (OPP). The products are processed according to the real orders. The determination of the OPP place is a challenging question for the companies, moving this point towards the end of the production line, provides better responsiveness. While moving it towards upstream, increases the flexibility. This concept is depicted as follows:

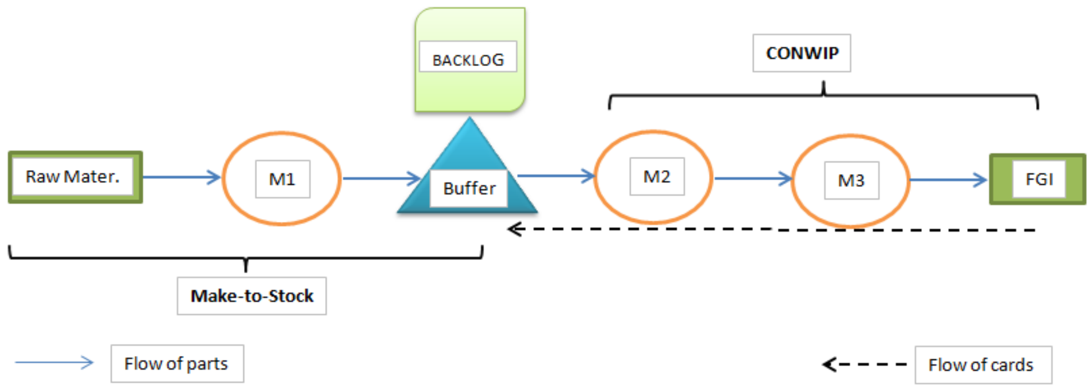

Fig. 3 Placing the buffer

4.3 Implementation in Pull Systems

The application of CONWIP to pure pull systems is easier than the others. This is because CONWIP itself is already a pull based system. The company employing pull system is familiar with the main principles. But for CONWIP, the pulling process will not be among the stations, but there will be one global WIP level for the whole production system. Again, we need to keep in mind Li's four key conditions for implementing CONWIP which were:

i) Production control approaches, ii) Shop layout, iii) Setup time reduction and iv) quality.

The firm that employs pure pull system has already lean approach to production, reduced setup times and important quality assurance system. Shop layout may be changed to cellular layout, it is not already so. And again, we mention that close monitoring of the performance measures of the CONWIP system should be done.

4.4 Implementation in SME's

Another study by Gastermann et al. (2011) discusses the implementation of CONWIP in Small and Medium sized companies (SME's). They point out that for SME's it is very difficult to implement pure pull systems like kanban. This is because most of the SME's either do not have enough resources for this or they have difficulties in handling such systems. In this sense, CONWIP is a simple approach and is easier to manage because there is only one set of cards in the whole system. Due to the nature of the CONWIP systems, flow times are more predictable. Another advantage of it is that, SME's sometimes need to change the order of processing the order according to the importance of the customer, which can be done in CONWIP system. At the end, the authors point out that the real performance of CONWIP system is difficult to compare.

5. CONCLUSION

In this paper, the CONWIP system was explained. We started with explanation of different approaches to production, and then moved to CONWIP system. The advantages of CONWIP system and its help in managing the production system were explained. The findings show that it in some cases kanban system is not applicable and pure push systems result in low performance of the system. In this case, CONWIP is applicable to more cases and does not need as much effort as pure pull systems. The cases that CONWIP would have more and less impact was another topic discussed.

Then, the implementation of CONWIP system was explained based on real case examples. The performance of CONWIP system was described for jobshops, pull and push systems. The integration of CONWIP with production planning and control based ERP system was also explained.

The topics and findings in this paper are based on the available material in the literature.

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